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(71) Applicant: **Telefonaktiebolaget L M Ericsson (Publ)**
126 25 Stockholm (SE)

(72) Inventors:
- **Berg, Magnus**
  11229 Stockholm (SE)
- **Dam, Henrik**
  2000 Fredriksberg (DK)

(74) Representative:
Söderman, Päivi Karin Lisbeth et al
Christer Mildh,
Ericsson Radio Systems AB,
Ericsson Research
164 80 Stockholm (SE)

(54) **A method and apparatus for uplink scheduling**

(57) The present invention relates to methods for performing uplink scheduling of packet data when using adaptive antennas. In the solution according to the invention the uplink scheduling information is transmitted either in the whole coverage area of the base station or in an antenna beam towards the mobile for which the scheduling information is intended. All other data packets are transmitted in an antenna beam towards the mobile station for which the data are intended. By adopting the proposed solution it is possible to use adaptive antennas in a system carrying e.g. GPRS/EGPRS traffic. The carrier to interference gain introduced by adaptive antennas produces a pronounced increase in system performance.

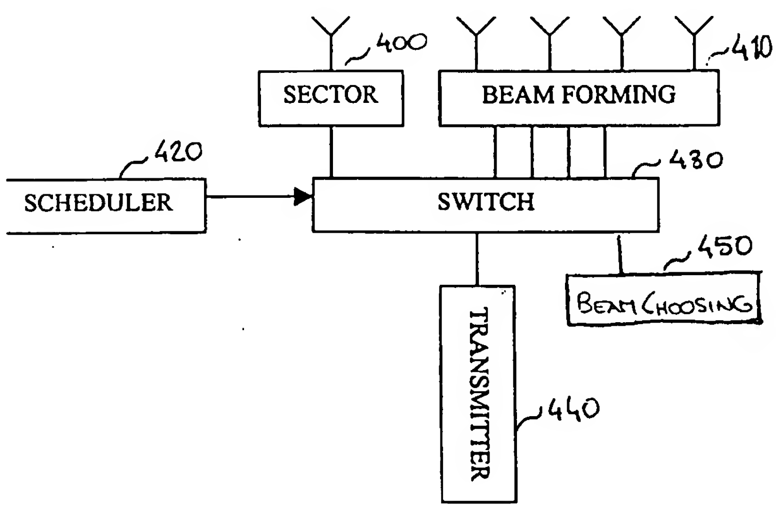

Figure 4.

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Description

TECHNICAL FIELD OF THE INVENTION

[0001] The present invention relates generally to methods for using adaptive antennas in cellular mobile telephone systems, and more particularly the invention relates to a method for performing uplink scheduling of packet data when using adaptive antennas.

[0002] The invention also relates to an arrangement for carrying out the method.

BACKGROUND OF THE INVENTION

[0003] It is anticipated that a large part of the future growth of wireless communication will be data traffic. Due to the "burstiness" of data traffic, the spectrum is more effectively used if the users share a common resource. An efficient way of sharing a resource is to use packet data. Thus, a great effort has been made in standardising a protocol for transmitting packet data in a GSM mobile communication network. This protocol is called GPRS (General Packet Radio Service) with future enhancements in EGPRS (Edge GPRS).

[0004] The GPRS protocol enables more than one mobile station to use the same timeslot or timeslots. This is done by time multiplexing users on the same radio resource. When starting a transmission the mobile station is assigned one or more timeslots in up- and downlink. In the assignment the mobile stations are given a temporal bit flow identity (TFI) and an uplink state flag (USF). The TFI is attached to the data blocks in order to identify the terminating mobile station of the transmitted block. In the downlink all mobiles are listening to the assigned timeslots and try to decode all blocks but only considers the blocks with corresponding TFI's.

[0005] The preferred method for scheduling the uplink is to use the USF, which is attached to user data in a downlink block. A mobile station is allowed to transmit an uplink block on a following time slot if it detects its USF in the corresponding downlink block. This method is called dynamic assignment. Another method for scheduling the uplink is to use an entire downlink block, i.e. when a mobile station is signalling uplink channel request, the reply from the network is a bitmap telling the mobile station what timeslots in what TDMA-frames the mobile station should use. The bitmap is transmitted to the mobile station in a dedicated data block. This method is called fixed assignment.

[0006] Adaptive antennas, here defined to be an antenna system that is able to change its characteristics to changes in the network, have several interesting properties. One of the most important features of an adaptive antenna system is that the base station is able to detect the direction to the mobile station and can thus transmit dedicated information in an antenna beam towards a desired mobile station. An antenna beam is defined as any signal transmission deliberately covering only a part of a cell, and a cell is defined as the total coverage area of a base station. This implies that the downlink signal is not transmitted in the entire cell resulting in lower interference in the system. Adaptive antennas have been shown to increase the system downlink C/I as much as 6dB compared to a regular system using sector-antennas. The interference level generally determines the channel reuse patterns. Because the interference level is reduced a channel reuse pattern can be formed in which channels are reused more frequently, thus increasing the capacity of the network. If the reuse pattern is left unchanged the C/I of the communication links is increased. Thus, the reduced downlink interference can be used either for increasing the number of users in the system or for increasing the C/I of the communication links.

[0007] The increased C/I of the communication links can in its turn be used to produce a significant throughput increase in a system carrying GPRS/EGPRS traffic. This is mainly due to link adaptation, which transforms communication link improvements into a throughput increase. In EGPRS a number of different coding schemes and two modulation methods are used to ensure maximum throughput at the current communication link quality C/I, i.e. the payload per transmitted data block varies with the quality of the communication link. A communication link having high quality can be used for a higher data transmission rate either by applying higher modulation or lower coding. Thus, it is obvious that there is a large potential in applying adaptive antennas in systems carrying GPRS/EGPRS traffic.

[0008] However, a problem exists with uplink scheduling when using adaptive antennas since user data and scheduling information usually terminates at different mobile stations. If the mobile stations are spatially separated there is a problem transmitting in an antenna beam since communication is optimised for only one of the mobile stations.

[0009] One possible solution of forming antenna beams, which permit other remote communication stations to detect the communication signals transmitted to a selected remote station, is described in WO-98/33233. More particularly the document solves the problem by using at least two antenna beams active at the same time to also cover mobile stations for which the transmission is not intended. The purpose is mainly to use the signal energy transmitted in the downlink for enabling complexity reduction in the mobile station and for facilitating the tracking of the downlink signal in a successive timeslot, such as e.g. in DAMPS (Digital Advanced Mobile Phone System).

[0010] The solution according to WO-98/33233 has the disadvantages of having to use two antenna beams active at the same time causing interference and overhead. The main purpose is also not to perform uplink scheduling as in the present invention, but instead to use the signal energy received for, e.g. AGC (Automatic Gain Control) adjustments and for reducing the com-

plexity in the mobile station.

SUMMARY OF THE INVENTION

[0011] The present invention provides a solution to the protocol problems concerning how to perform uplink scheduling of packet data when using adaptive antennas.

[0012] In the preferred uplink-scheduling mode of GPRS/EGPRS the scheduling information is attached to user data. It is likely that the user data and the scheduling information are terminated at different mobile stations. Hence, if the mobile stations are separated the communication does not reach every intended receiver of the data.

[0013] One object of the present invention is thus to provide uplink scheduling of packet data in a radio communication system using adaptive antennas.

[0014] Another object of the invention is to reduce the amount of overhead necessary for uplink scheduling of packet data in a communication system with adaptive antennas.

[0015] The above mentioned objects are achieved by transmitting the data blocks containing scheduling information either in the whole coverage area of the base station or in an antenna beam towards the mobile station for which the scheduling information is intended. All other data blocks are transmitted in an antenna beam towards the mobile station for which the data are intended.

[0016] In a first embodiment of the invention the data block carrying the scheduling information is transmitted in the whole coverage area of the base station. The mobile station for which the scheduling information is intended is then certain to receive the scheduling information. This method is sub-optimal for adaptive antennas but if USF of granularity 4 is used, i.e. the USF schedules four consecutive uplink blocks for the receiving mobile station, at least 75% of the blocks can be transmitted in a antenna beam which will provide a significant system C/I increase.

[0017] In a second embodiment of the invention the data block containing the scheduling information is transmitted in an antenna beam towards the mobile station for which the scheduling information is intended. Then, there is a risk for a larger block error probability at the mobile station for which the data is intended. However, an ARQ (Automatic Request for Retransmission) algorithm ensures that the data block is retransmitted if the mobile station cannot decode it correctly. It is also possible to use the data received by the mobile station but not decoded correctly by using incremental redundancy.

[0018] In a third embodiment of the invention an entire downlink block is transmitted in an antenna beam to a specific mobile station containing a bitmap, which informs the mobile station what time slots in what TDMA frames to use for uplink transmission. If the number of blocks, which are being scheduled, is large the positive effects of adaptive antennas will be much larger than the increasing overhead. There is however a trade off between the number of scheduled blocks and the dynamics of the system. If too many blocks are scheduled the connection behaves more like a circuit-switched connection than packet oriented and thus the spectrum is not as efficiently used.

[0019] The embodiments of the invention can preferably be implemented by software code segments, and e.g. be stored in any of the relevant nodes of a mobile communication system, such as a base station, a base station controller, a mobile services switching centre, a packet control unit etc.

[0020] By adopting the proposed solution it is possible to use adaptive antennas in a system carrying GPRS/EGPRS traffic. The combination of the ARQ scheme and link adaptation of GPRS/EGPRS and the carrier to interference gain introduced by adaptive antennas produces a pronounced increase in system performance.

[0021] The term "comprises/comprising" when used in this specification is taken to specify the presence of stated features, integers, steps or components but does not preclude the presence or addition of one or more other features, integers, steps, components or groups thereof.

[0022] Although the invention has been summarised above, the method and arrangement according to the appended independent claims 1, 8 and 10 define the scope of the invention. Various embodiments are further defined in the dependent claims 2-7, 9 and 11-12.

BRIEF DESCRIPTION OF THE DRAWINGS

[0023]

Figure 1	illustrates the problem of uplink scheduling when the mobile stations are spatially separated.
Figure 2	shows the RLC/MAC-block structure of GPRS.
Figure 3	shows an example of uplink scheduling according to the invention.
Figure 4	shows a realisation of dynamic assignment according to one embodiment of the invention.
Figure 5	shows an antenna diagram with directional beams and a sector antenna.

DETAILED DESCRIPTION

[0024] The present invention describes a method and a system for providing uplink scheduling of packet data in a communication system using adaptive antennas. In the preferred uplink-scheduling mode of GPRS, dynamic assignment, the scheduling information is attached to user data. It is likely that the user data and the scheduling information are terminated at different mobile stations. If the mobile stations A and B are spatially sepa-

rated as in figure 1, the problem is obvious. Suppose that mobile station A is the termination point for the scheduling information and mobile station B is the termination point for user data. Suppose also that the transmission is directed to mobile station B in an antenna beam, then mobile station A can not receive the scheduling information intended for it.

[0025] The above problem concerning uplink scheduling is basically solved by transmitting the data blocks containing scheduling information either in the whole coverage area of the base station or in an antenna beam towards the mobile station for which the scheduling information is intended. The solution will be further described with reference to figures 2-5.

[0026] Figure 2 shows in detail the radio block structure of the smallest entity in GPRS/EGPRS, the RLC/MAC-block. Each RLC/MAC-block consists of a MAC header, an RLC data block and a block check sequence (BCS). The MAC header comprises an uplink state flag (USF) and the RLC data block consists of an RLC header, containing a block type indicator and power reduction fields, and RLC data. The RLC/MAC-block is channel coded, interleaved and mapped onto four normal GSM bursts. A mobile station thus has to receive all four bursts to receive the RLC/MAC-block. The scheduling information is found in the USF, which gives the corresponding mobile station permission to transmit on the uplink.

[0027] In figure 3 a first embodiment of the invention is illustrated. Assume that mobile station A and mobile station B is spatially separated, as shown in figure 1, and cannot be reached with an antenna beam. Assume also that the downlink transmission is directed to mobile station B and that mobile station A is listening on timeslots TN0-TN3 for its USF. The data block carrying the scheduling information is in this embodiment transmitted in the whole coverage area of the base station. The mobile station, for which the scheduling information is intended, mobile station A, is then certain to receive the USF. The dark shaded blocks in the drawing, containing USF A, are transmitted in multiple antenna beams or with a sector antenna, thus covering the whole or large parts of the cell, and the grey shaded blocks are transmitted in an antenna beam. It can be seen that when scheduling the uplink for mobile station A, it is necessary to transmit the information in the whole coverage area of the cell but when scheduling the uplink for mobile station B it is enough to transmit the data in an antenna beam since the transmission is directed to mobile station B. The method is sub-optimal for adaptive antennas but if USF of granularity 4 is used, i.e. the USF schedules four consecutive uplink blocks, light grey in the drawing, for the receiving mobile station, at least 75% of the blocks can be transmitted in an antenna beam providing a significant system C/I increase.

[0028] An example of realisation of the above method is shown in figure 4. The system comprises a sector antenna 400 and an antenna array 410 for transmitting directional antenna beams. The system also comprises a scheduler 420 that transmits information to a switch 430 determining whether or not to transmit the downlink data block from the transmitter 440 on the sector antenna 400. The switch 430 also comprises a beam-choosing algorithm 450, for choosing the right antenna beam. It is the scheduler 420 that determines whether the downlink data block from the transmitter 440 is carrying scheduling information.

[0029] The scheduler 420 can preferably be implemented by software code modules determining if the downlink data blocks from the transmitter 440 is carrying scheduling information and transmitting a signal to the switch 430 determining whether the downlink data block should be transmitted by the sector antenna 400 or the antenna array 410.

[0030] In a second embodiment of the invention data blocks containing scheduling information is instead transmitted in an antenna beam towards the mobile station for which the scheduling information is intended. Then there is of course a risk for a larger block error probability at the mobile station for which the user data is intended. However, an ARQ (Automatic Request for Retransmission) algorithm ensures that the data block is retransmitted if the mobile station cannot decode it correctly, i.e. when an error in the BCS (Block Check Sequence) is detected. Some of the user data might still reach the mobile station for which it is intended because of radio reflections and side lobes from the main lobes. In figure 5 the side lobes can be seen at approximately -14dB. User data received by the mobile station but not decoded correctly can still be used to some extent due to incremental redundancy, i.e. the soft values of the first received frame is used together with the soft values of a retransmitted frame. The retransmitted frame may have been coded in a different way, which further increases the information, thus more data can be correctly decoded.

[0031] A further feature of the second embodiment is to use information about the positions of the mobile stations in the scheduling algorithm in order to minimise the number of data blocks transmitted in an erroneous antenna beam. For example should mobiles that are not spatially separated be multiplexed on the same packet data channel (PDCH), i.e. the same timeslot and frequency. This reduces the need for retransmissions, since both scheduling information and user data terminates at mobiles covered by the same antenna beam, and thus the system capacity increases.

[0032] In a third embodiment of the invention an entire downlink block is transmitted in an antenna beam towards a specific mobile station containing a bitmap, which tells the mobile station what time slots and what TDMA frames to use for uplink transmission, so called fixed assignment. If for example the medium number of blocks allocated with every fixed assignment is 20, the overhead increases with 5%. If the number of blocks, which are being scheduled, is large the positive effects

of adaptive antennas will be much larger than the increasing overhead. There is, however, a trade off between the number of scheduled blocks and the dynamics of the system. If too many blocks are scheduled at the same time the connection behaves more like a circuit-switched connection than a packet oriented and thus the spectrum is not as efficiently used.

[0033] The invention being thus described, it will be obvious that the same may be varied in many ways. Such variations are not to be regarded as a departure from the scope of the invention, and all such modifications as would be obvious to a person skilled in the art are intended to be included within the scope of the following claims.

Claims

1. A method for performing uplink scheduling of packet data in a mobile communication system that includes at least one base station transmitting to a plurality of mobile stations within its respective area of coverage, the at least one base station using adaptive antennas
the method **characterised**

    in that data blocks carrying scheduling information are transmitted from the base station either in the whole coverage area of the base station or in an antenna beam towards the mobile station for which the scheduling information is intended; and

    in that all other data blocks are transmitted in an antenna beam towards the mobile station for which the data are intended.

2. The method of claim 1 **characterised** in that said scheduling information is a flag informing a mobile station that it has an uplink radio resource reserved.

3. The method of claim 2 further **characterised** in that said scheduling information is an uplink state flag.

4. The method of claim 3 further **characterised** in that said uplink state flag is of granularity 1 or 4.

5. The method of any of claims 1-4 further **characterised** by using incremental redundancy when decoding the data received in the mobile station for which user data was intended.

6. The method of any of claims 1-5 further **characterised** in that mobile stations covered by the same antenna beam are multiplexed on the same packet data channel.

7. The method of claim 1 **characterised** in that said scheduling information consists of an entire downlink data block scheduling the uplink for a specific mobile station and that said downlink data block is transmitted in an antenna beam towards the mobile station for which the scheduling information is intended.

8. A computer program product comprising a computer readable medium, having thereon:
computer program code segments for performing the method of any of claims 1-7 when said product is run on a computer.

9. The computer program product according to claim 8 **characterised** in that it is stored in a scheduler.

10. A base station for performing uplink scheduling of packet data in a mobile communication system with a plurality of mobile stations in the coverage are of the base station

    the base station **characterised** by comprising

    first means for transmitting data blocks carrying scheduling information either in the whole coverage area of the base station or in an antenna beam towards the mobile station for which the scheduling information is intended; and

    second means for transmitting all other data blocks in an antenna beam towards the mobile station for which the data are intended.

11. The base station in claim 10 wherein in the first and second means are **characterised** by comprising

    a sector antenna and an adaptive antenna array connected to a switch controlled by a scheduler, wherein said scheduler determines whether the data blocks from the transmitter contains scheduling information or not; and

    beam choosing means for directing the antenna beam towards the intended mobile station.

12. The base station according to any of claims 10 or 11 further **characterised** by
means for multiplexing mobile stations covered by the same antenna beam on the same packet data channel.

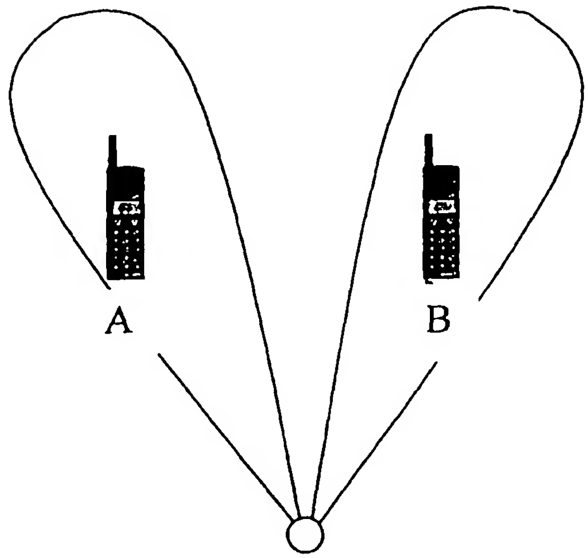

Figure 1.

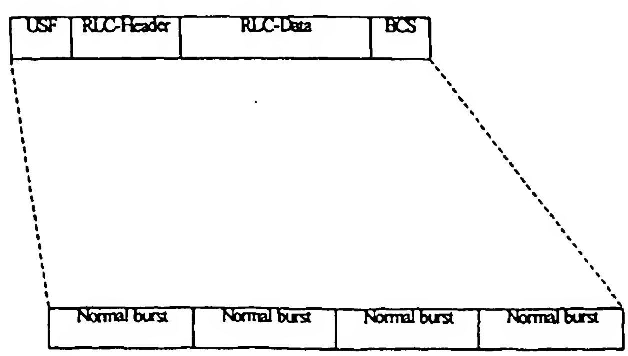

Figure 2.

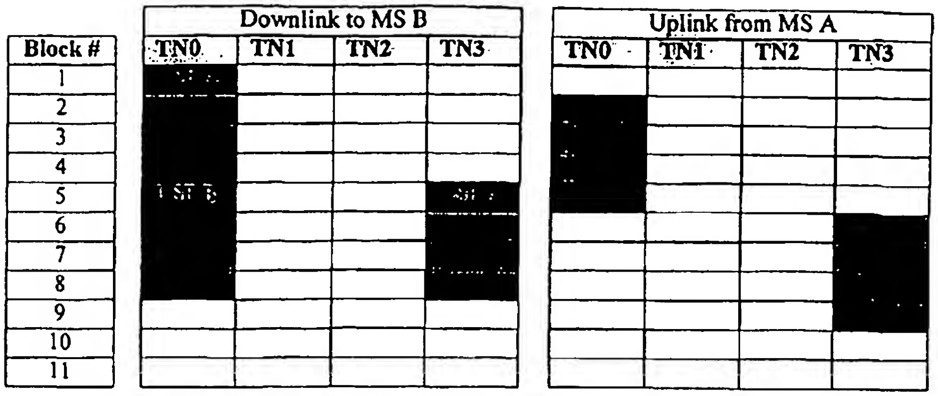

Figure 3.

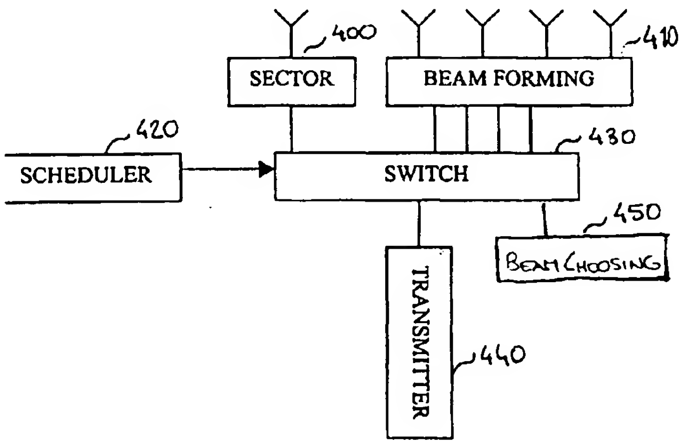

Figure 4.

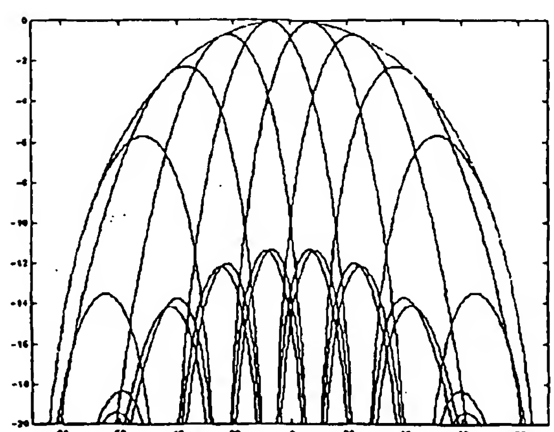

Figure 5.

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EUROPEAN SEARCH REPORT

Application Number
EP 99 85 0159

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int.Cl.7)
X Y	WO 99 41918 A (ERICSSON TELEFON AB L M) 19 August 1999 (1999-08-19) * abstract * * page 5, line 24 - page 6, line 18 * * page 7, line 9 - page 9, line 5 * * page 10, line 6 - line 12 *	1-4,6-8, 10,12 5	H04B7/02
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X	WO 98 37706 A (MOTOROLA INC) 27 August 1998 (1998-08-27) * abstract * * page 5, line 32 - page 8, line 29 *	1-3,6-8, 10,12	
X	US 5 697 066 A (ACAMPORA ANTHONY) 9 December 1997 (1997-12-09) * abstract * * column 1, line 35 - column 3, line 15 *	1,10	TECHNICAL FIELDS SEARCHED (Int.Cl.7)
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The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
THE HAGUE	20 March 2000	Lustrini, D

CATEGORY OF CITED DOCUMENTS

X : particularly relevant if taken alone
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